INTERACTION OF SELF-HEALING EPOXY COATING AND MICROENCAPSULATED INHIBITOR FOR THE CORROSION PROTECTION OF MAGNESIUM ALLOYS.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang Al-Sultan Abdullah or any other institutions.

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ABSTRAK

Kakisan logam merupakan salah satu faktor kerugian bagi sektor perindustrian, contohnya dalam bidang pengangkutan, kejuruteraan awam dan marin serta dalam bidang kejuruteraan perubatan. Pengecatan seperti salutan epoksi adalah salah satu kaedah terbaik untuk melindungi logam daripada kakisan. Walau bagaimanapun, salutan tertakluk kepada kejadian luaran seperti retak mikro yang memendekkan hayat perkhidmatan salutan. Oleh itu, salutan tradisional perlu dinaik taraf kepada salutan penyembuhan sendiri, untuk menyembuhkan retak dan melindungi logam daripada kakisan. Dalam kajian ini, salutan epoksi digabungkan dengan mikrokapsul yang mengandungi madu dengan kepekatan berbeza (0%, 10%, 20%, 30% dan 40% v/v), Aloe vera (10 % v/v) dan minyak biji rami (50 % v/v) dengan 800 rpm dan 1100 rpm sebagai kelajuan kacau. Kajian ini bertujuan untuk menyiasat nilai kepekatan madu dan kelajuan kacau mikroenkapsulasi yang paling optimum dalam menahan kakisan aloi Mg dan untuk menilai kelakuan kakisan aloi Mg bersalut epoksi penyembuhan sendiri dalam persekitaran yang menghakis. Mikrokapsul ini berjaya dihasilkan melalui pempolimeran in-situ mikrokapsul poliurea formaldehid (PUF) dan dibenamkan ke dalam salutan epoksi,. Mikrokapsul dan morfologi salutan epoksi dinilai dengan mikroskop imbasan elektron dengan analisis sinar-X penyebaran tenaga (SEM dengan EDX). Menggunakan Fourier Transform Infrared Spectroscopy (FTIR) dan spektroskopi UV-Vis, sifat fisio-kimia mikrokapsul telah disiasat. Spektroskopi impedans elektrokimia (EIS) dan polarisasi potensiodinamik (PDP) digunakan untuk menilai prestasi pertahanan sampel aloi Mg bersalut epoksi penyembuhan sendiri. Imej daripada mikroskop optikal mendedahkan mikrokapsul memiliki diameter dari 56 μm hingga 83 μm dan saiznya berkurangan apabila kelajuan kacau semasa sintesis meningkat. Permukaan mikrokapsul dengan kelajuan kacau 800 rpm kelihatan lebih kasar daripada mikrokapsul yang dihasilkan oleh kelajuan kacau 1100 rpm. Spektrum FTIR mendedahkan bahawa minyak biji rami dan madu telah berjaya dikapsulkan dalam cangkerang PUF. Morfologi permukaan salutan penyembuhan diri menunjukkan permukaan licin dan kehadiran mikrokapsul di kawasan keratan rentas lapisan. Anggaran dengan aplikator filem nipis menghasilkan 100 μm ketebalan salutan. Madu juga dikenal pasti sebagai komponen kawasan yang sembuh kerana pengesanan kalium, natrium, dan kalsium menggunakan analisis unsur EDX, yang menentukan tindak balas madu terhadap persekitarannya untuk membina lapisan pelindung. Analisis PDP menentukan bahawa salutan penyembuhan sendiri terdiri daripada 30% (v/v) madu, dikacau pada 800 rpm, menawarkan perlindungan kakisan tertinggi pada aloi Mg, dengan ketumpatan arus kakisan yang lebih rendah, Icorr (0.032 μA/cm2) daripada yang terdedah kepingan magnesium (1050 μA/cm2), menunjukkan kelakuan pempasifan sementara. Plot EIS Nyquist mempamerkan lengkung yang menyerupai separuh bulatan untuk setiap sampel, memaparkan pemindahan cas aktif antara salutan dan larutan natrium klorida (NaCl). Pada 30% (v/v) dan 20% (v/v) kepekatan madu, salutan penyembuhan sendiri dengan rintangan pemindahan cas tertinggi, masing-masing dikacau pada 800 rpm dan 1100 rpm, disebabkan oleh sedikit pengagregatan dan pengasingan lapisan pelindung yang mengandungi madu pada permukaan bersalut. Oleh itu, mengintegrasikan minyak biji rami berkapsul PUF dengan ekstrak madu ke dalam salutan epoksi meningkatkan kadar rintangan kakisan logam Mg. Memandangkan potensi salutan penyembuhan diri ini, ia boleh difikirkan untuk digunakan dalam industri untuk mengurangkan proses kakisan dan mengurangkan kos dan kesan kakisan.

ABSTRACT

Metal corrosion is one of the loss factors for industrial sectors, for example, in transport, civil and marine engineering, and medical engineering. Painting or epoxy coating is one of the best methods to protect metal from corrosion. However, the coating is subject to external events such as micro-cracks that shorten the service life of the coating and allow the corrosion process to occur. Therefore, traditional coatings must be upgraded to self-healing coatings, combined with encapsulated healing agents or corrosion inhibitors to heal cracks and protect metal from corrosion. In this study, the epoxy coating was combined with microcapsules containing honey with different concentrations (0%, 10%, 20%, 30% and 40% v/v), Aloe vera (10% v/v) and linseed oil (50% v/v) with 800 rpm and 1100 rpm as stirring rate. This study aims to investigate the optimum value of honey concentration and stirring rate of microencapsulation in resisting the corrosion of Mg alloys and to evaluate the corrosion behavior of self-healing epoxy coated Mg alloys in a corrosive environment. These microcapsules were successfully produced through in-situ polymerization of polyurea formaldehyde (PUF) microcapsules and embedded into an epoxy coating. Microcapsules and epoxy coating morphology were evaluated by scanning electron microscopy with energy-dispersive X-ray analysis (SEM with EDX). The physio-chemical properties of the microcapsules were investigated using Fourier-transform infrared spectroscopy (FTIR) and UV-Vis spectroscopy. Electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization (PDP) were used to evaluate the defensive performance of self-healing epoxy-coated Mg alloy samples. The images from the optical microscope revealed that the microcapsules range in diameter from 56 µm to 83 µm. The size decreases as the rate of stirring rate during synthesis increases. The surface of the microcapsules with a stirring rate of 800 rpm looks rougher than the microcapsules produced by a stirring rate of 1100 rpm. FTIR spectra revealed that linseed oil and honey were successfully encapsulated in the PUF shell. The surface morphology of the self-healing coating shows a smooth surface and the presence of microcapsules in the cross-sectional area of the layer. Approximation with a thin film applicator results in 100 µm coating thickness. Honey was also identified as a component of the healing area due to the detection of potassium, sodium, and calcium using EDX elemental analysis, which determines the reaction of honey to its environment to form the protective layer. PDP analysis determined that the self-healing coating composed of 30% (v/v) honey, stirred at 800 rpm, offered the highest corrosion protection on the Mg alloy, with a lower corrosion current density, Icorr (0.032 µA/cm2) than the exposed magnesium sheet (1050 µA/cm2), showing transient passivation behaviour. The EIS Nyquist plot exhibits a curve that resembles a half-semicircle for each sample, displaying the active charge transfer between the coating and the sodium chloride (NaCl) solution. At 30% (v/v) and 20 %(v/v) honey concentrations, the self-healing coating with the highest charge transfer resistance stirred at 800 rpm and 1100 rpm, respectively, is due to slight aggregation and segregation of the honey-containing protective layer on the coated surface. Therefore, integrating PUF-encapsulated linseed oil with honey extract into the epoxy coating increased the corrosion resistance rate of Mg metal alloys. Considering the potential of this self-healing coating, it is conceivable to use it in industry to reduce the corrosion process and impact.

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